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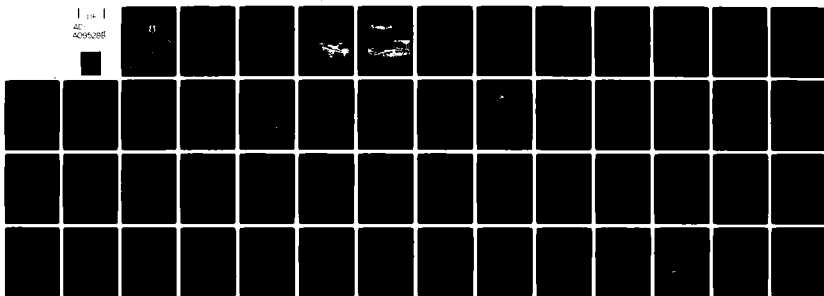
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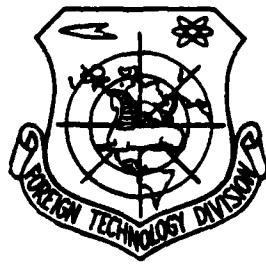
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# FOREIGN TECHNOLOGY DIVISION



INTERNATIONAL AVIATION  
(Selected Articles)

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The American Developed Model of the AV 8B/C  
"Sparrow Hawk"

At present, developed models of three American improved "Sparrow Hawk" vertical takeoff and landing fighters are being test flown by the American Navy. Among them, the AV-8B (photos 1 and 2) system was made from a refitted AV-8A and was test flown in 1978 and the beginning of 1979 respectively. Another is the AV-8C (photo 3) which was test flown at the end of 1979.

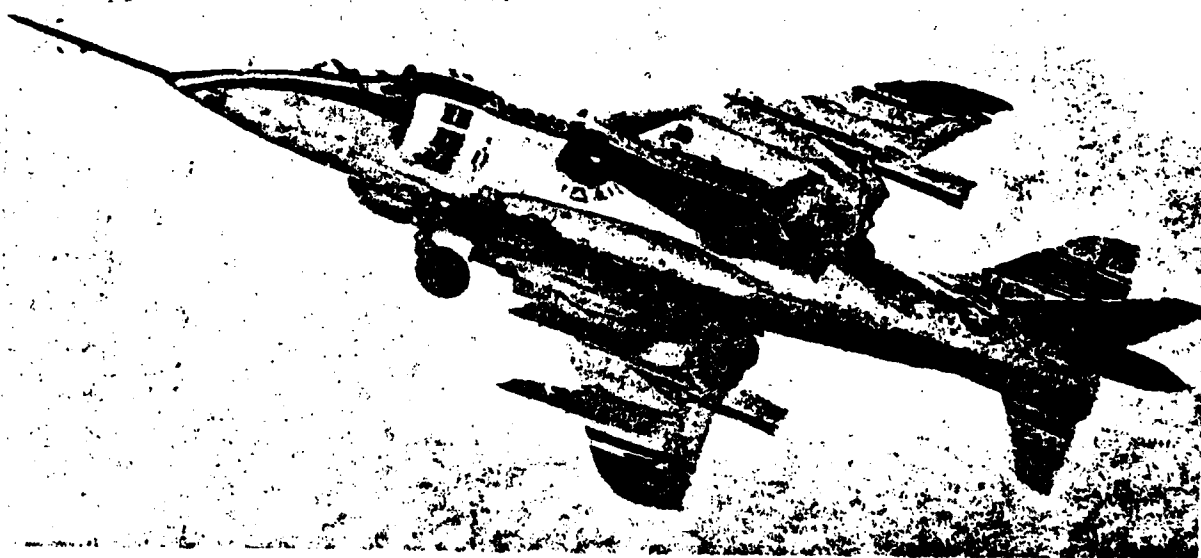


Photo 1



Photo 2

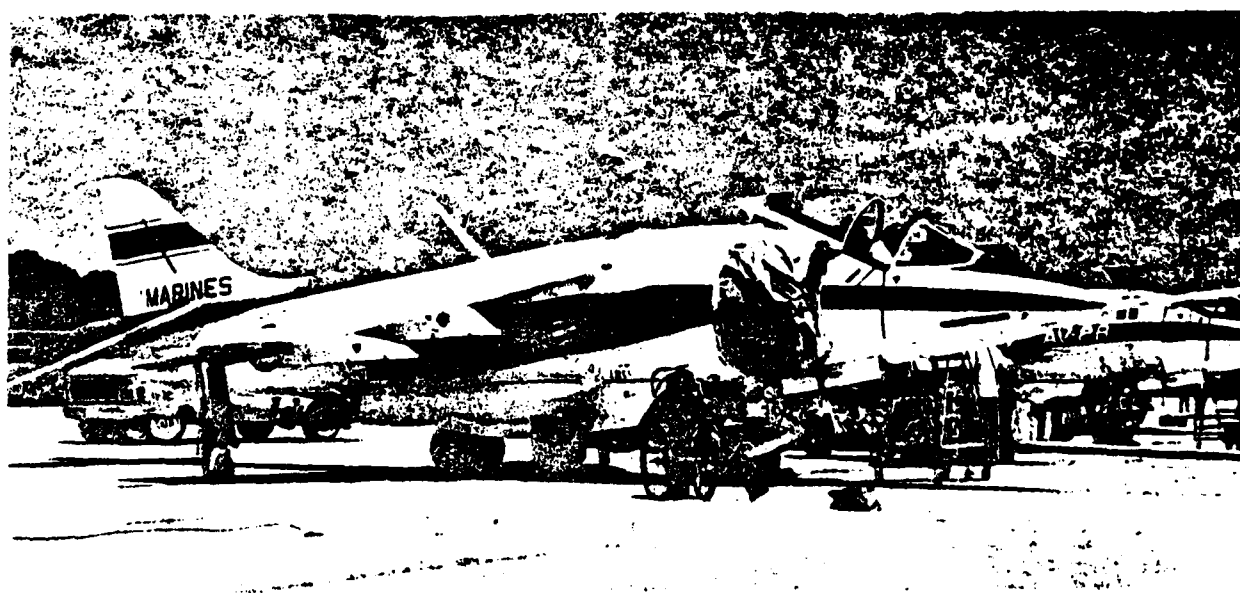


Photo 3

## FOREIGN VERTICAL TAKEOFF AND LANDING FIGHTERS

by Jin Yunwen

In future warfare, large airfields are naturally the first targets to be attacked and moreover fighter planes that depend on large airfields also find it difficult to give air support to ground troops. Because of this, the use of the vertical short distance takeoff and landing method has been a problem that has continually been investigated during the last 20 years. From the end of the 1950's to the middle of the 1960's, the United States, the Soviet Union, England, France and West Germany have all formulated individual plans, carried out research on test planes and made massive efforts on vertical takeoff and landing fighters. However, up until the present, internationally there are only two types of actively used military vertical takeoff and landing fighters, the British "Sparrow Hawk" and the Soviet Union's Yak 36. Although other aircraft, such as West Germany's VJ-101 and VAK 191, France's "Baerzhake(?) ("Unreal Image (?) III V") and the United States' XV-4A and XV-5A have all test proven their technical feasibility yet all have halted actual aircraft development for

different reasons.

As to the question of the future of the vertical takeoff and landing fighter, at present, opinions still vary. Because of the still numerous existing problems in utilization, the airforces of each country are not too enthusiastic about it. Yet, the navies of all of these nations are giving serious attention to it because this type of aircraft can extend its use to various medium sized warships which can avoid the dependence of a fixed wing ship based aircraft on a costly large aviation launching vessel. Moreover, it can be flexibly used to increase fighting power. Most of the future takeoff and landing fighters will primarily be used by the navy.

#### 1. The Applications of Two Types of Presently Used Vertical Takeoff and Landing fighters

##### The Application Experiences and Existing Problems in the "Sparrow Hawk" Fighter

The development of the "Sparrow Hawk" began in 1957, the first mooring hanging test of the tested prototype P. 1127 occurred in October, 1960 and in the next year there was achieved interim flight from hanging to forward flight. The produced "Sparrow Hawk" GR-MK1 was test flown in December, 1967 and in July, 1969 was

regular equipment for the British Air Force. Following this, the United States Marines contracted to buy 110 of the aircraft numbered AV-8A and they were delivered for use in 1971. The Spanish Navy contracted to buy 12 of the aircraft. The Purchasing of the "Sparrow Hawk" reached to 273 which were all already delivered in 1978.

The "Sparrow Hawk" is a subsonic single seater vertical short distance takeoff and landing fighter which is designed for low air to ground attacks. The aircraft is fitted with a turning nozzle "Flying Horse" turbine engine (thrust 9,675 kilograms). The two pairs of nozzles are symmetrical with the center of the aircraft and are arranged on the two sides of the fuselage. They can turn downwards 98.5° causing the spray to go downwards and form four air streams which is the jet lift for vertical takeoff and landing. When the aircraft takes off vertically, lands and hangs, the reaction operating system of the fuselage head, tail and wing tip control the flight conditions. Because aircraft weight is rather high, in testing, the employed thrust directional change in forward flight can cause medium and low air mobility and air fighting power for the aircraft. Because of this, besides the aircrafts major use in close distance support and tactical reconnaissance, it can also be used for partial air defense.

The "Sparrow Hawk's" use in ground vertical and short distance takeoff and landing possesses the good points of mobility, decentralized equipment and it does not depend on a base system. The aircraft raises the existing power and accompanying battle line speed shift under battle and sudden attack conditions and the proper support power for the ground troops. Usually it can be deployed from a permanent, large scale base and during battle can give logistic support of a concealed troop base and deploy 6 to 10 aircraft to a range of 10 to 15 kilometers around the base. It can also be used for vertical takeoff and landing of 1 to 4 aircraft to be dispersed to forward scattered points and each day each aircraft can attack 8 times.

The greatest problem of the "Sparrow Hawk" is that the range of vertical takeoff is short, its capacity to carry bombs is small and its logistic supply is difficult thus causing its use to be limited.

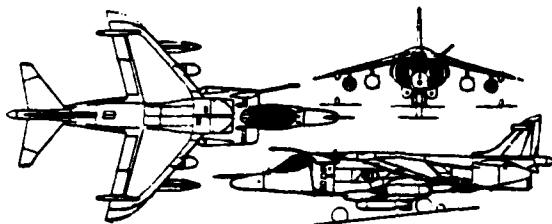
The weight of the "Sparrow Hawk" vertical takeoff must be less than 90% of the engine's thrust which limits the carrying weight and range. For example, when the greatest carrying weight is 1,360 kilograms, the vertical takeoff fighting radius is only 92 kilometers and if a low/low/low launch attack form is used, it can further be decreased to 80 kilometers. To make up for the insufficiency in

carrying weight and range, as far as possible they generally require the use of a short distance takeoff form and when takeoff is 300 meters and the weight is unchanging it must also have a perfected security communications guidance system<sup>of 660 kilograms</sup> and then it can fully bring into play its fighting effectiveness. In the last ten years, the "Sparrow Hawk" has only been used by the British air force in land operations. Yet, because it can have short distance takeoff and landing from medium and small army vessels and can also sustain various antiground and antiaircraft battle tasks, the problems of logistic signal communications are also better resolved. Aside from the navies of the United States and West Germany, the British Navy also purchased an improved "Sea Sparrow Hawk" model.

When the "Sparrow Hawk" takes off vertically from a vessel, weight loss is too great and it requires the use of short distance takeoff to increase the weight and range. To further shrink the deck running distance, Britain tested the "oblique plate running takeoff" technique (see front cover). In the front part of the deck was mounted a 27 meter x 24 meter oblique plate and by adopting the oblique running takeoff technique, the aircraft could decrease its takeoff speed and thus shrink its short running distance. For example, when the oblique angle of the oblique plate is  $20^{\circ}$ , the running distance could shrink in half and perhaps increase takeoff load by 900 kilograms. Moreover, when the aircraft is used on a

vessel, it is not influenced by wind speed, wind direction and deck movement. This increases takeoff safety. According to reports, if this type of technique is successfully tested, it can improve the design of aircraft carriers.

Looking at the eight years in which the United States Marines used the AV-8A, the training of a flight crew for the "Sparrow Hawk" was a big problem. In the first half of 1978, there were 29 serious accidents and 26 aircraft were lost. Among them, 60% were due to factors created by the flight crew and during the last half of the year, these occurred in the flight range of vertical short distance takeoff and landing. According to reports, training is the major reason for the high rate of accidents. The initial flight crew of the AV-8A were carefully chosen from among experienced flight personnel. However, the continuity from the training group to the flight group is often lost which influences the quality of flight personnel. At present, they are in the process of strenuously improving training methods.



“鹰”式战斗机的三面图

Diagram of Three Sides of the "Sparrow Hawk" Fighter

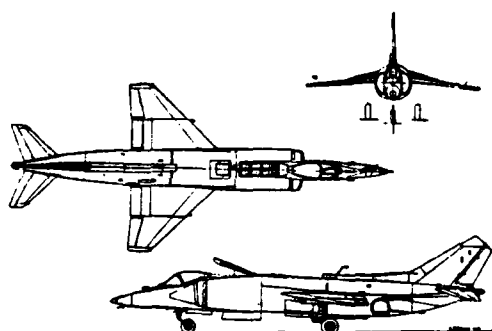
## The Soviet Union's Yak-36 Vertical Takeoff and Landing Fighter

The Soviet Union's investigation of the vertical takeoff and landing technique dates from the end of the 1950's. In reviewing aviation, in 1967, they developed three types of lift engine short distance takeoff and landing prototypes and turning nozzle vertical takeoff and landing test aircraft "free paintings". In 1973, they again carried out vertical takeoff and landing tests of the "Moscow" model vertical lift from an aircraft carrier. In July, 1976, when the Yak 36 was put into an inland sea on the Soviet "Jipu(?)" aircraft carrier, there were official reports that it had already been put into service. According to reports, development work began at the end of the 1960's.

The Yak 36 is a single seater ship based attack plane and has limited antiaircraft capabilities. It uses a lift engine and turning nozzle engine joined form. The two stages of lift engines are vertically arranged in the cabin in the rear part of the fuselage and the mounting angle slopes 15° towards the back. When in operation, the shutter type air intake cover is opened which can provide 3,200 kilograms of thrust lift. One turbojet engine with a thrust of 8,000 kilograms is placed in the rear fuselage and its pair of nozzles can turn 105° down from a level position to the rear (it can slope forward 15°) and the thrust of the lift

power engine forms a V shaped thrust vector gauranteeing the vertical takeoff, landing and hanging of the aircraft.

The wings of the aircraft in a semiopened wing position can fold. The lower side of the inner wing section has two hanging frames which can hang bombs, rockets, air to air missiles, a GSh 23 double tube artillery suspended cabin, a reconnaissance cabin and an auxilliary fuel tank.



雅克-36 的三面图(取自日本《航空年鉴》)

Diagram of Three Sides of the Yak 36 (Taken from Japan's "Aviation Yearbook")

Based on actual investigation, this aircraft's interim time is long and yet when taking off and landing it is very level and stable. It is calculated that it has a computer controlled automatic stabilization system. Because vertical takeoff and landing

consumes about 30% of the aircraft's fuel, when the aircraft carries a low 1,000 kilograms, the fighting radius is 240 kilometers and when the outside hanging photograph cabin and the two 500 liter auxiliary fuel tanks carry out high altitude reconnaissance, the largest fighting radius is increased to 556 kilometers.

The Yak 36 uses three engines which also increases the breakdown rate. Foreign commentaries consider that the breakdown of any one engine can bring disaster for the aircraft. Besides this, when taking off and landing, the smoke discharge of the main engine is critical, the smoke trail length reaches 30 kilometers and thus is easily spotted.

Foreign publications estimate that the Yak 36 can very well be able to develop into a coast base model and its deployment in Europe is possibly only a question of time.

## 2. Existing Developed Plans

The British Navy's "Sea Sparrow Hawk" FRS MK1

In 1975, the British government formally approved the development of the navy improved model of the "Sea Sparrow Hawk" which was to equip the "Invincible" class straight deck guidance

cruiser. The first produced model was tested in August, 1978 and in 1980 began to be formally used in the British Navy. 34 were contracted.

The fighting tasks of the "Sea Sparrow Hawk" are: long range naval patrol and naval force antiaircraft (at high altitudes the greatest fighting radius is 740 kilometers), attacks against naval and land targets (greatest fighting radius is about 450 kilometers), reconnaissance and antisubmarine (at low altitudes, it can fly for 1 hour and search 70,000 kilometers<sup>2</sup> of ocean).

The "Sea Sparrow Hawk" is an improved version of the airforce's "Sparrow Hawk" GR MK3. Its airframe, engine and mechanical system are 90% the same and yet its fighting equipment and navigation/attack system are 90% new. The front of the fuselage is newly designed adding on a large nose and uses "Lanhu (?)" radar and other new electronic equipment. The cockpit was raised 280 millimeters to improve the visual field, the inside of the cockpit was enlarged, there was installed a new cockpit environmental system to improve the fighting efficacy of a crew members operating multifunctional weapons and it was refitted with Madding Baker (?) Company model 10 bomb firing seats. The equipment also included a flat sight instrument's new whole number type navigation/attack system.

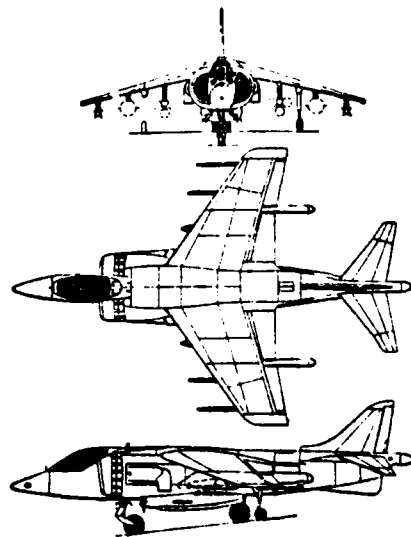
## The AV 8B Plan of the United States Marines

The United States Marines plan to transform the light attack power interim into vertical short distance takeoff and landing. To do this, 60% of the airmen aircraft will be changed into vertical short distance takeoff and landing aircraft (including vertical lift planes). It is calculated that first the AV 8A improved AV 8B aircraft will be put into use in 1985 to replace the present A4 and AV 8A.

Early, in 1975, the AV 8B plan began to be demonstrated and because of cost limitations it was decided to first use the two AV 8A refitted prototype aircraft. The first was manufactured in 1977. The two prototypes were completely tested in 1979 and reached predetermined demands. Yet, the United States Defense Department under the excuse of reducing navy models prepared to buy a large number of F18 attack model A18 and not to support the AV 8B plan. Because of this, whether or not the AV 8B will go into production is still not certain.

The main tasks of the AV 8B are: to attack land targets and naval vessels, to cooperate with antisubmarine fighting and to provide subsonic limited antiaircraft.

The main improvements on the AV 8B include the use of super inspection field wings and slotted closed wings and jet ring quantity increased lift equipment; the use of compound materials; the modifying of the admission duct plan; the strengthening of the takeoff and landing frame; the raising of the cockpit; the adding of a high capacity angle speed bombing system; and for the fuselage artillery cabin to add a striped shape to make a box shaped surface e fect increased lift apparatus. According to reports, after these measures are used, the carrying weight and navigation of the AV 8B can be twice that of the AV 8A. Its dependability and maintenance are also raised, its weapons system is most suitable for direct air support and its greatest carrying weight can reach 3,630 kilograms. The hanging frame on the outer side below the wing carries "Rattlesnake" air to air missiles and the aircraft artillery has fixed self protective capability.



AV-8B 的三面图

Diagram of Three Sides of the AV 8B

## The Plan for the United States Navy's Vertical Short Distance Takeoff and Landing Aircraft

In 1976, when former American President Ford was examining the navy's five year shipbuilding plan, he decided to use a 60,000 ton medium aircraft carrier to replace the plan for building large carriers. Under these conditions, the head of the United States Navy suggested that the plan for ship based aviation crews be changed to that of vertical short distance takeoff and landing. Their reason was that the development of the high thrust weight ratio engine and miniaturized technique provided the requirements for this and that cost would not result in the great excesses of conventional takeoff and landing aircraft. The goal of the plan was, during the period from 1991 to 2005, to step by step use the vertical short distance takeoff and landing aircraft to completely replace and reach the service life of conventional aircraft and to combine the active aircraft and create two to three models. To do this, a plan for three A,B,C models of vertical short distance takeoff and landing aircraft was suggested.

The major uses of the A model are in antisubmarine, prealert, land attacks and in search and rescue of multiuse subsonic aircraft. The original plan was that manufacture was to begin in 1986, use was to begin in 1991 and it was to replace the S 3A, E 2C and CH 54 ship

based aircraft and the vertical lift aircraft.

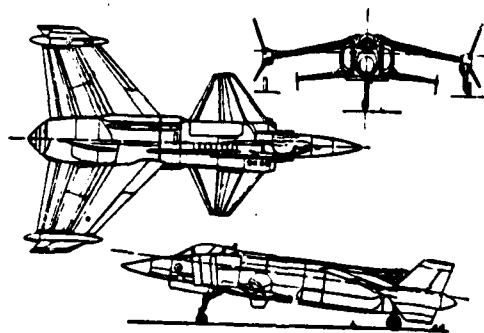
The model B is used in intercepting, attack and reconnaissance multiuse high performance supersonic fighters and beginning in 1994 it was to replace the F14, A6, Av 8A/B and F18/Al8.

The C model is a multiuse rotary wing aircraft and its development is still not listed in the agenda.

Based on statistics, the cost for the A and B model plans will reach 5 and 8 billion U.S. dollars respectively. Because of this, the sources for funds are still a big problem. At present, the focus of the development of the United States Navy is on the B model fighter and for the A model to only carry out technical and planning research.

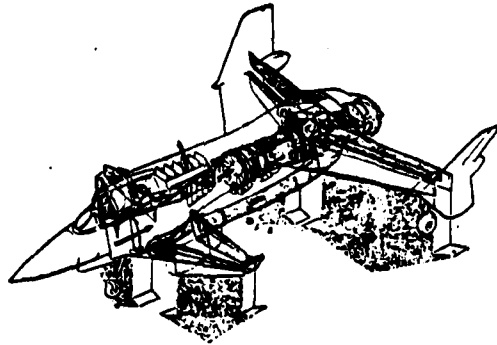
In setting out to research the B model aircraft plan, some use the lift power + lift power cruise propellant system of the Yak 36 such as the commonly used power company plan. Yet, the one that has gained the most attention is the XFV 12A thrust increased lift wing vertical takeoff and landing aircraft plan of the Lockheed (?) International Company. They have already decided to manufacture two test prototype aircraft to carry out flight tests and the first one came out in August, 1977.

Fundamentally, the thrust increased lift wing propellant system can also be considered a type of lift power/cruise engine. Yet, it does not employ a rotating nozzle to deflect the thrust but the exhaust passes to the increased lift system in the area of the aircraft center. The XFV 12A has a F401 turbofan engine and when in hanging and interim flight, this causes 90% of the gas to not be emitted from the back nozzle towards the rear. It also passes the border of the wing and duck wing spread installed piping and is emitted from the crack of the front to rear contracted tube in the deflected wing flap and then produces thrust lift power. At the same time, the high speed emitted jet stream sucks in about 8 times the surrounding air and produces an increase in thrust lift power. The downward emitted gas stream speed and temperature are both relatively low and the level of noise, externally picked up substances and ground erosion are greatly decreased.



XFV-12A 的三面图(取自日本《航空年鉴》)

Diagram of Three Sides of the XFV 12A (Taken From Japan's "Aviation Yearbook")



XFV-12A 的布局及其垂直起降原理图

#### Diagram of the Layout and Vertical Takeoff Principle of the XFV 12A

The XFV 12A test prototype aircraft system is a combination of an A4 aircraft front fuselage, nose and takeoff and landing frame and an F4 admission channel, wing case and newly designed components. In August, 1977, after it came out of the factory, at the end of the same year it had basically completed ground testing. After this, mooring tests were completed on the simulated training frame of NASA's Lanli (?) Research Center (see International Aviation, 1979, no. 11, inside front cover) which tested and verified its basic design principle. Yet, the thrust increased lift did not reach predetermined goals and it required modification in wing and duck wing design. Up to the present, it has not been free flight tested.

The United States Navy has formulated a separated stage

examination and approval policy for the entire vertical short distance takeoff and landing aircraft plan. If the manufacture of this type of aircraft is not successful, they can resume development plans for the conventional aircraft.

### Conclusion

Since the middle of the 1950's, although foreign nations have carried out widespread research and development of the vertical takeoff and landing technique and already have two types of vertical takeoff and landing fighters in actual service, yet there still remain some important, unresolved problems in the design of this type of aircraft. Firstly, the operating quality of the vertical takeoff and landing aircraft is a very prominent problem. The reason many early vertical takeoff and landing aircraft were not able to be used was often because operational quality and boundary were not good. The high accident rate of the United States AV 8A is also related to this. This is an important field of present day foreign research.

Secondly, the selection and development of the propellant system is also a major problem.

The propellant systems of the previously mentioned three types

of aircraft basically reflect their possible suitability in supersonic vertical takeoff and landing fighters developed abroad. For the advantages and disadvantages of the three types of propellant system plans, to satisfy utilization demands at supersonic speeds, there is still much work that needs to be done. For example, the problems of the turning nozzle turbofan engine's outer case, the raising of the lift power engine's thrust weight ratio to 3:1 and offering actual use of the lift power increased lift wing system all await resolution. There must be developed a new style engine such as the changing cycle engine which has higher efficiency in various flying conditions.

Generally, because present experience and data on the supersonic vertical takeoff and landing layout is insufficient, it is still difficult to determine the good and bad of the selection of a propellant system and its layout plan. Because of this, foreign nations think that based on existing technical programs, the development of 4 or 5 years of concentrated energy is still needed and then they will be able to provide the necessary conditions to technologically manufacture a type of functional supersonic vertical short distance takeoff and landing fighter.

Technical Data On Foreign Vertical Takeoff And Landing Fighters  
and their Tests

	Sparrow Hawk	Yak 36	AV 8B	XFV 12A
<b>Measurement</b>				
Wing spread, meters	7.70	7.5	9.23	8.69
Aircraft length, meters	13.91	16.0	13.08	13.39
Aircraft height, meters	3.45	3.5	3.44	3.15
Aircraft surface, meters	18.68	15.8	21.37	27.2 + 7.72
<b>Weight</b>				
Air weight, kilograms	5,580	5,500	5,693	6,260
Regular takeoff and landing weight, kilograms (vertical/short distance)	8,161/			
Carried fuel weight inside aircraft, kilograms	2,295		3,180	2,763 liters
Carried bomb weight, kilograms	2,270	1,000	3,630	
Largest takeoff weight, kilograms (vertical/short distance)	8,165/ 10,430	9,980/	8,550/ 13,400	8,845/ 11,000
<b>Performance</b>				
Greatest speed				
Low altitude	M=0.95	M=0.95	M < 1	M=1.5 to 1.6
High altitude		M=1.05		
Lift rate, meters/minute				
Functional ceiling, meters	15,240			
Action radius, kilometers	80 to 660	240 to 280	185 to 2,775	

## FLIGHT TESTING AND VERIFICATION OF

### THE UNITED STATES YAV 8B

by Feng Mirong

In 1971, the United States Marines introduced the British "Sparrow Hawk" short distance takeoff and landing fighter. After several years of test use, they thought it was extremely useful for supporting army ground troops. Because of this, they signed a contract with the MacDonald Douglas Aircraft Company to technically improve the AV 8A and to develop an advanced vertical short distance takeoff and landing aircraft called the AV 8B, to make a second generation light model attack plane. It was planned that it would completely replace the presently used A4 and AV 8A.

In the 1977 fiscal year, the marines used 330 million U.S. dollars to refit two AV 8A into AV 8B prototypes which was the YAV 8B. The YAV 8B was first test flown on November 9, 1978. According to an August 20, 1979 report, test flight work was finished. Altogether it flew 185 times, accumulating 173 flying hours.

In comparison to the AV 8A, the AV 8B adopted the following technical improvements (see chart 1):

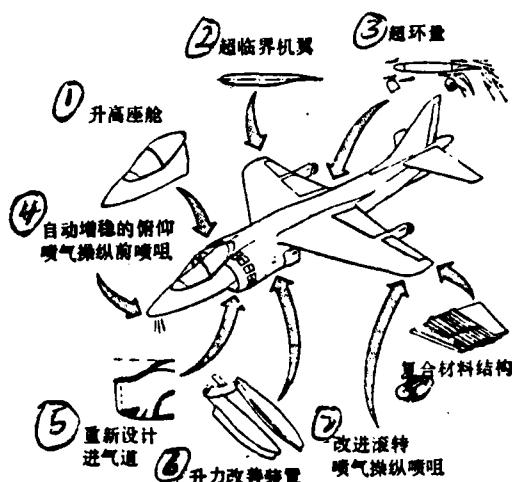


图1 AV-8B的性能和操纵品质的改善

Chart 1 Improvements of the Performance and Operating Quality of the AV 8B

1. High raised cockpit
2. Super critical wing
3. Super ring quantity
4. Automatic increased stabilized pitch nozzle control front spray
5. Newly designed intake duct
6. Compound material structure
7. Improved turning jet controlled spray
8. Improved lift power apparatus

1. The power apparatus uses an improved "Sea Sparrow Hawk's" "Flying Horse" 104 so as to improve antierosion. Further, it is

necessary to improve the engine's dependability and maintenance. The produced model AV 8B uses an enlarged thrust F402 RR405. The longest functional life span goal is 1,000 hours.

2. The use of a super critical wing to reduce transonic drag, to enlarge the lift drag ratio and to improve the aircraft's mobility and cruise performance. At the same time, stored fuel inside the wing can be increased 75%.

3. Rationally arrange the wing and engine jet pipe position. The large surface single slotted wing flap and jet pipe join for dynamic deflection and the jet driven air blows passed the flap wing enlarging the speed error above and below the wing surface forming a super ring quantity (see chart 2) and causes the AV 8B short distance takeoff lift to increase 3,100 kilograms.

4. To improve the ground effect and reduce the repeated intake quantity of the engine jet, on the bottom of the fuselage is added a receiving and transmitting crosswise separate plate in between the side strip and the suspended cabin on the plane's artillery suspended cabin so as to form a lift power improved apparatus. This type of apparatus can be closed by the ground reflection of the engine jet and tests have proven that intake temperature can fall 20° C. After using this type of apparatus, the

thrust of vertical takeoff can increase 544 kilograms.

5. The redesigned engine intake duct. The refitting of a pair of auxiliary admission gates cause the vertical short distance takeoff and landing admission surface to increase from its original 3.6 feet<sup>2</sup> to 8.4 feet<sup>2</sup>. The refitted fixed intake mouth measurement accords with discharge requirements of high altitude cruising and decreases the overflow drag. The lip shape is changed from the original rounded arc shape to a 2:1 ellipse and also the throat surface is enlarged (from 9.2 feet<sup>2</sup> to 9.7 feet<sup>2</sup>).

6. The redesigning of the jet controlled spray. The shift of the front spray toward the front is 9 inches and inclines somewhat towards the front. The front and rear control spray and increased stability and state maintain the system's connection and can reduce the pilot's responsibilities. Because the wing spread is enlarged 5 feet, turning control efficiency is increased. The horizontal roll control spray was also redesigned which reduced the horizontal roll/yaw sympathy.

7. For the wing, they used a graphite epoxy compound material which occupied 63% of the structural weight and lightened the weight by about 150 kilograms.

8. The high raised cockpit improved the visual field and cockpit indication. Compound materials were also used for the cockpit which could lighten the weight by about 25 kilograms.

9. Improvement of dependability and maintenance. The direct maintenance of man hours of each flight hour is decreased from 21.7 hours of the AV 8A to 16.9 hours. The strategic condition is increased from 50% to 75%.

After refitting, the load/navigation ratio of the AV 8B is at least double that of the AV 8A and the capacity to hold fuel in the aircraft is increased 50%. The AV 8B carries a 9,200 pound outer hanging substance, uses four 300 gallon auxiliary fuel tanks and the turning field range can reach 2,500 nautical miles (after the fuel is used up, the auxiliary fuel tanks are discarded). When the aircraft is filled with fuel and carries seven MK 82 bombs and machine guns the fighting radius is 215 nautical miles. If it carries 3,150 pounds of fuel on the outside, its fighting radius can increase to 630 nautical miles.

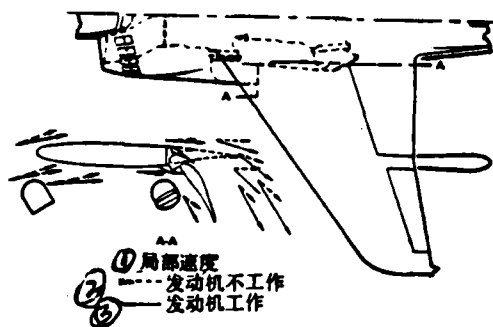


图2 超环量的增升装置

Chart 2 Super Ring Quantity Increased Lift Apparatus

1. Partial speed
2. Engine doesn't operate
3. Engine operates

YAV 8B modifications are basically the same as the AV 8A plan only the cockpit is not modified and it still maintains the increased stabilization system of the AV 8A. The purpose of the YAV-8B flight tests was to test the performance and operational quality of the AV 8B. The results of the flight tests showed that the AV-8B improvement plan was successful and reached the performance demands of the marines and navy aviation systems command. Charts 3 and 4 are comparisons of the AV 8B and AV 8A. Below are the results of the flight tests.

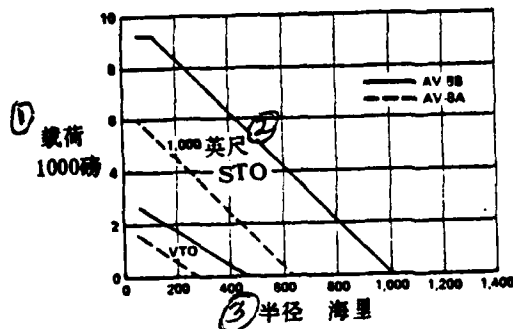


图3 载荷-航程的比较

Chart 3 Comparison of Load and Range

1. Load 1,000 pounds
2. 1,000 feet
3. Radius, nautical miles

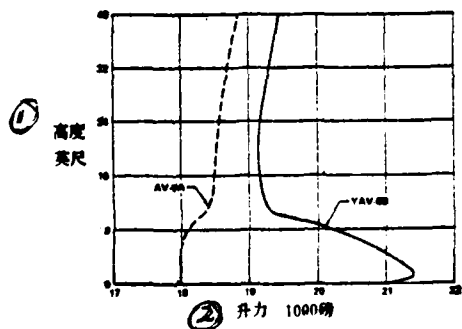


图4 垂直起飞升力的比较

Chart 4 Comparison of Vertical Takeoff Lift Power

1. Elevation, feet
2. Lift power, 1,000 pounds

## Flight Performance

**Vertical Takeoff** At the beginning of March of 1979, during the 23rd flight, the YAV 8B carried out heavy load vertical takeoff. Takeoff weight was 8,985 kilograms and it carried seven hanging frames, a suspended artillery cabin and two rattlesnake missiles. It demanded that interim flight begin at a height of over 50 feet. Before this, the climbing rate reached to at least 300 feet/minute and during the entire interim flight it was necessary to maintain a regular increase in speed and climbing rate. Flight results are shown in table 1. Takeoff weight was revised to the fixed value of 8,575 kilograms which is 835 kilograms greater than the AV 8A.

Table 1

	23rd Flight	Navy Demands	23rd Flight Revised Value	AV8A
Environmental Temperature (°F)	47.5	89.8	89.8	89.8
Engine condition	S/N8834	lowest	lowest	stand.
Vertical takeoff weight (kilograms)	8,985	8,555	8,575	7,740

Table 2

	39th Flight	Navy Demands	Flight Result Corrected Value	AV8A
Takeoff weight (kilograms)	12,715	12,678	12,678	9,462
Environmental temperature (°F)	46.2	89.8	89.8	89.8
Head wind (nautical miles/ hour)	13	0	0	0
Engine condition	S/N8834	lowest	lowest	stand.
Running distance	598	1,000	963	963

Vertical Landing After the YAV 8B uses the improved lift power apparatus, it is provided with added lift power and when vertically landing the required power is decreased. Moreover, it decreases exhaust suction which causes the jet pipe temperature to maintain relative stability when the aircraft is landing.

Short Distance Takeoff and Landing The increased lift state YAV 8B's aileron deflection is  $15^\circ$ , wing flap deflection and jet pipe move together, when jet pipe deflection is  $25^\circ$ , wing flap deflection is  $25^\circ$  and when jet pipe deflection is  $50^\circ$  or greater wing flap deflection reaches its greatest position of  $61.7^\circ$ . See chart 5 for the performance of the YAV 8B short distance takeoff.

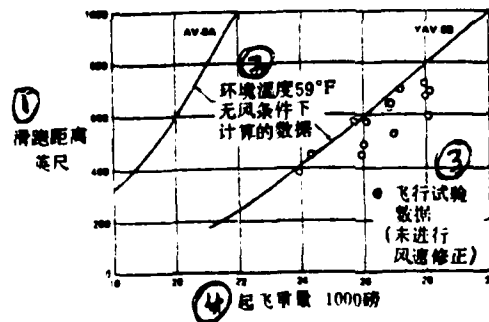


图5 短距起飞地面滑跑距离

Chart 5 Short Distance Takeoff Ground Run Distance

1. Run distance, feet
2. Data calculated under calm conditions at temperature of  $59^\circ\text{F}$
3. Flight test data (without wind velocity correction)
4. Takeoff weight, 1,000 pounds

The 39th test flight tested and verified a fixed performance (see table 2).

Its takeoff weight was 12,715 kilograms and the running distance of 598 feet was corrected to a fixed requirement value of 963 feet which is 37 feet shorter than demanded. Also its takeoff weight (12,678 kilograms) was 3,216 kilograms greater than that of the AV 8A. The takeoff process was: the jet pipe position at the beginning of the run was 10°. When at a predetermined speed (102 nautical miles/hour equivalent air speed), jet pipe deflection was estimated at a position of 55° and the wing flap followed automatic deflection and went from 25° straight to the highest deflection position. All along the jet pipe maintained about a height of 50 feet and began interim flight. At this time, the total takeoff distance was only 1,940 feet.

Because of the use of the above mentioned increased lift apparatus, the power required for the YAV 8B short distance touchdown was small and the approach speed was low. This expanded the thrust range of the return flight, decreased water loss in hot weather, extended the life span of the engine and shortened running distance.

#### Flight Quality

Jet Lift Power State. Because of the previously mentioned improvements, the responsibilities of the pilot when the YAV 8B is in a jet lift power state is about 65% less than that of the AV 8A.

The roll thrust used for the newly designed roll operated spray is 29% larger than that of the AV 8A. Also, because the operating arm of force of the YAV 8B is longer, the role operating moment of force is about 72% larger. This kind of roll increased stabilization was improved and the pilot's control was even more effective. Further, because they changed the direction of the roll operating jet this caused the crosswise induced yaw to decrease about 90% and further lightened the responsibilities of the pilot. With the servomotor installed in the YAV 8B's pitch jet operating front spray, the pilot can, based on conditions, whenever necessary open the valve and directly control the pitch increased stabilization system. To control the AV 8A pitch increased stabilization system it is necessary to go through the pitch jet operated rear spray.

Test flights have proven that the above improvements cause the YAV 8B to be extremely stable when hanging, especially vertically. When mobile, operation induces smoothness, dependability and accuracy.

With the use of the improved lift power apparatus, the YAV 8B is completely smooth when vertically taking off and landing. This overcame the AV 8A's "bumping" phenomenon occurring in the ground effect influence area.

Semijet Lift State    The low moment of force produced by the wing flap and reflecting aileron is great and because of this, when in semijet lift flight, vertical operation range is enlarged and stabilization is improved when suspended on the outside. Test flights showed that in short distance takeoff, vertical operation range is doubled. Further, when leaving the ground effect influence area, the pitch matching level change is easy to control. Even when in the very unstable state of carrying a 300 gallon auxiliary fuel tank, there is also the highest upward tendency. In this way, the responsibilities of the pilot are lightened.

When the YAV 8B is in interim and mobile flight, vertical section deflection is smooth, the responsibilities of the pilot are small and operation range is large.

When the YAV 8B is in a semijet lift state, the improvements of crosswise operation are mainly the evident decrease of crosswise operation to match the flat inclined slide induced roll. This is because the roll decrease induced by the improvements and side incline (induced by the angle of attack and outside hanging) of the YAV 8B's effective crosswise operation (jet operation and aileron operation) results in causing the needed crosswise operation for the YAV 8B to match the even inclined slide induced roll to decrease about 50%. This type of operation is even more flexible and safe.

A NEW METHOD FOR RAISING FIGHTER MOBILITY  
("THRUST DIRECTIONAL CHANGE IN FORWARD  
FLIGHT" FOR THE "SPARROW HAWK" AIRCRAFT)

by Shui Wen

"Thrust directional change in forward flight (VIFF)" also called "thrust vector control (TVC)" is a commonly used turning engine exhaust jet in forward flight. This type of method is used for "Sparrow Hawk" aircraft and it has been proven that it can raise fighting mobility.

The "Sparrow Hawk" aircraft is based on the manufacturing requirements of being able to carry out vertical short distance takeoff and landing. After it became regular equipment for the British Airforce in 1969, it functioned as a low altitude attack plane. Because at that time air to air fighting capability was not required they did not look seriously at adopting the turning jet as a method to raise air combat capabilities. In 1971, the United States Marines began to outfit the AV 8A (the United States code

name "Sparrow Hawk") and used it as a direct air support fighter. At the same time, they enthusiastically developed testing research so that this aircraft's potential abilities and accuracy could use appropriate military tactics. The first test was carried out in 1971, although because this aircraft's wing load was great, its speed low (subsonic speed), its rear visual field was not good thus causing air fighting capability to be bad, yet it appropriately used thrust directional change in forward flight which raised its mobility. In 1971, NASA also employed the "Sparrow Hawk" prototype test aircraft "Benji(?)" for simulated initial tests. Afterwards, they further carried out air combat tests of the "Sparrow Hawk" against the T38, F4 and F86. Tests proved that if they used thrust directional change in forward flight, the aircraft's effectiveness would be greatly raised. The test results also drew serious attention from the British. Beginning in 1972, NASA and the British Ministry of Defense cooperated in implementing a separate stage joined test plan, expanded the flight sphere using "thrust directional change in forward flight" and investigated each related mobile movement when in combat.

#### The Use of "Thrust Directional Change in Forward Flight"

The main results produced by "thrust directional change in forward flight" are the increase in the aircraft's turning speed

and decrease of the aircraft's speed thus raising air combat ability and the precision and subsistence against ground attacks.

#### 1. Use In Air To Air Combat

According to reports, the reduction in speed produced by thrust directional change results in a six fold reduction in speed. When the deflected nozzle reduces speed, the engine continually maintains great thrust and when necessary, it can immediately shift to cause the aircraft to be in an accelerated state. When the nozzle has a small angle deflection, this is sufficient to produce a fixed jet lift and raise the overload capacity. Tests show that when turning there is instantaneous movement, the overload can be raised 1.2g (maintained for 2 to 3 seconds) and the static overload can be raised 0.25g. Because of this, in a very high speed range, turning speed can be increased  $1.5^{\circ}$  to  $2^{\circ}$ /second. This is extremely beneficial for air combat mobility. Besides this, the reaction control system used for vertical short distance takeoff and landing can also further raise mobility and can especially realize high speed changes in low speed flights. The "Sparrow Hawk's" flight personnel need not worry about operational quality because the speed is very small and will break down. Although the opposing aircraft is not the same, because in a full turn it is forced to decrease speed or nearly lose speed thus it becomes difficult to operate.

The use of thrust directional change in air combat can also occupy a dominant psychological position. Victory or defeat in combat often depends on the experience and skill of the flight personnel. The flight personnel based on the continual flight path changes of both sides correctly calculate the possible forward position of the opposition and afterwards operate their own aircraft to carry out the attack. Drawing support from thrust directional change for mobility in a high angle of attack is to draw in new parameters outside normal pneumatics causing the flight path to break away from the normal state and become incalculable. Because of this, the opposition flight personnel are made to feel "bottomless" and be psychologically reduced to an inferior position to the point of losing confidence in fighting. This has already been proven in actual test flights.

The use of thrust directional change in forward flight when in air combat can bring about the following mobile movements.

**Rapid Turns** When the nozzle is turned downwards this causes the aircraft to raise its nose. This not only enables the aircraft to speedily enter a turn but also because of the pneumatic total lift, the level tail downward load decreases and increases. When the nozzle turns downwards it also provides vertical movement in the flight path's thrust weight causing the total lift to increase to

3/4g. When there is a sharp decrease in speed turn, the largely decreased speed capability caused by the thrust directional change will improve the turning state. As soon as the nozzle rotation passes 20°, the reaction control system then begins to work automatically, increasing the operation and reaction capability of the revolving threefold axis. This is very useful in low altitude air combat.

Swift Jump Lift Movement When two aircraft are in close range combat both usually think of spiraling to shake off the opposition. Under this kind of situation, besides making circling movements, they can also carry out swift jump lift movements whereby both sides can continually change their kinetic energy and potential energy and attain advantageous positions. With the greatest thrust, the radius of a level flight turn is large and when swift jump lift turning, the speed in the highest part of the upper lift path is low, potential energy is great and the turning radius is smallest. The use of thrust directional change can cause flight speed to further decrease and the change is at an even greater altitude. The reaction control system guarantees the altitude control under low speed conditions at the path's highest position. After passing the highest position of the path it can make a large angle dive and use thrust directional change to accelerate speed. When reaching the limit, it can very quickly decrease horizontal

thrust in the entire thrust and pull and roll so as to get near the opposition. In this way, they use as far as possible the effective influence of the thrust directional change on vertical mobility (using gravitational action) and also fully use its accelerated and decreased speed capacity under full thrust conditions.

**Sudden Changes In Course** When the opposition is in a good position and has already reached a 700 to 800 meter rear firing position, the "Sparrow Hawk" can rely on thrust directional change to suddenly change course. This is a type of largest overload mobile movement and can force the opposition to rush forward. Afterwards, it can make a large overload circular roll, it can roll 360° upwards and the speed returns to the full thrust and pursuit of forward flight.

Besides this, the thrust directional change in forward flight can also integrate with the action of the reaction control system causing the nose of the aircraft to point to and take missile aim at the target. It can also cause the aircraft to draw support from the mobile movement to evade attacking missiles.

## **2. Use In Air To Ground Combat**

When entering in an antiground attack, they can draw support

from thrust directional change to make the needed mobility for fast searching of targets and after discovering targets it very quickly turns and enters a fighting position. When the directional change is in a dive, it can be used to control speed causing the aircraft to rapidly decrease speed and maintain a suitable speed for aiming. After ejecting the weapon it can also use a small drawn radius to change to diving or climbing and thus reduce the danger of ground attack. When there is a visible attack small target, it draws support from thrust directional change to make a small turn for aiming which is a very advantageous feature. After low altitude ejection of laser guided or televised guided weapons it can immediately make "straight angle turns" and thus it is not necessary to pass or approach the target space.

The majority of artillery of modern fighters are paralleled installed in the longitudinal axis of the fuselage and the artillery axis always forms a positive angle with the aircraft speed vector. If the artillery is aimed at a ground target, the aircraft then needs to make a very large angle dive. This causes some fighters when they are rushing straight towards the ground and cannot but draw to be unable to hit the target. The use of thrust directional change is helpful in artillery aiming. When the "Sparrow Hawk" aircraft turns its nose  $10^{\circ}$  to  $20^{\circ}$  it can cause the artillery axis to make a negative angle with the flight speed vector.

## Relevant Air Combat Tactics

The principle for the use of the method of thrust directional change in forward flight to carry out air combat are: to force the opposition to reduce speed to a nonoperative state and perhaps force the opposition to be placed in a position where they cannot use conventional tactics for fighting. Below are introduced several types of air combat tactics under different situations.

### 1. Countering The Turning Performance Of A Relatively Poor Supersonic Aircraft

**Forcing The Opposition To "Go Forward"** When the opposition approaches from the rear, the "Sparrow Hawk" aircraft can use thrust directional change to make a sudden left turn to evade the threat of the opposition's shells or missiles. Because the opposition attempts to follow, therefore both planes decrease speed in turning and gradually pull to the regular combat overload maximum of 6 to 7g. When entering a turn, the "Sparrow Hawk" depends on reducing speed quicker than the opposition and in the same overload it can make an even smaller radius turn. As a result, the opposition is forced to go forward in a turn of a greater radius and they cannot use their artillery or missiles for attack. At this time, the "Sparrow Hawk" has two choices: to go forward, turn the nozzle

level and escape or to accelerate, pursue the opposition and attack.

Forcing The Opposition To Enter An "Outer Circle" This is a widely used tactical move employed during World War Two and in the Vietnam War. As soon as one enters combat, whoever's turning radius is smaller can then get on the trail of the opposition being placed in an advantageous attack position. The "Sparrow Hawk" relies on directional change thrust and the reaction control system to be able to make a circle whose radius is 20% to 30% smaller than the oppositions and thus gain victory in air combat.

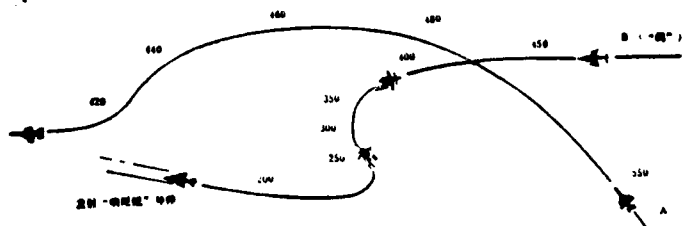


图1 迫使对方冲前(图中单位为海里/小时)

Chart 1 Forcing the Opposition to Rush Forward (units in chart are in nautical miles/hour)

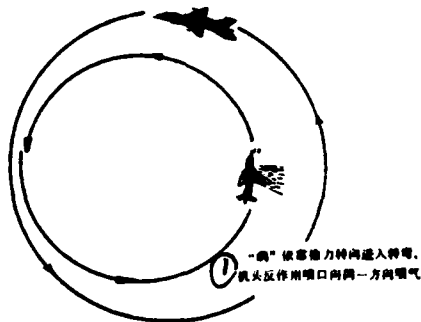


图2 迫使对方进入“外圈”

## Chart 2 Forcing The Opposition To Enter An "Outer Circle"

1. The "Sparrow Hawk" enters a turn depending on thrust directional change and the jet of the nose reaction nozzle faces the same direction.

The Use of Thrust Directional Change When Encountering In Battle. When two aircraft meet, the "Sparrow Hawk" aircraft uses a low 70 nautical miles/hour (130 kilometers/hour) speed to climb and employs thrust directional change to keep the nose pointed at the opposition so that it can fire weapons at any time. If the opposition does not withdraw from the fight and turns to attack (for example, see 3A in chart 3), the "Sparrow Hawk" can then draw support from the reaction control system to turn and it tails the opposition's descent.

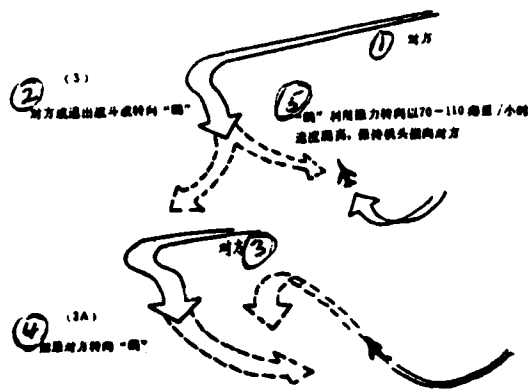


图3 双机遭遇

Chart 3 The Encountering Of Two Aircraft

1. Opposition
2. Opposition withdraws from combat or turns toward "Sparrow Hawk"
3. Opposition
4. If opposition turns toward "Sparrow Hawk"
5. The "Sparrow Hawk" uses a thrust directional change of 70 to 110 nautical miles/hour speed climb to maintain its nose pointed at the opposition

The Use Of Rapid Jump Ascending Turn Movement. When being pursued by the opposition, the main movement of the "Sparrow Hawk" aircraft is the rapid jump lift turn movement which is climbing to a high altitude and rolling to fly upside down. At the same time, the nozzle turns 20° causing the fuselage to be vertical. At this time, the trailing opposition is placed in a raised nose low speed condition and then the "Sparrow Hawk" dives down on the same path as the opposition is climbing. Because the peak of the "Sparrow

Hawk's "hudou (?)" seems to have no radian, the opposition will then have no means of calculating the collision point and also be unable to track.

If the opposition first uses a pull up turn to counter the turning movement of the "Sparrow Hawk", the latter can rely on thrust directional change to meet the opposition's climb and handle the opposition in a vertical movement. Soon afterwards, it again uses the thrust directional change method to turn downwards in back of the opposition and accelerates pursuit.

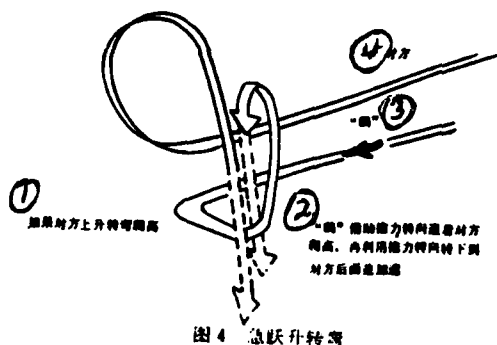


Chart 4 The Rapid Jump Ascending Turn

1. If the opposition ascends, turns and climbs
2. The "Sparrow Hawk" draws support from thrust directional change to meet the opposition's climb and again uses thrust directional change to turn downwards behind the opposition and accelerate.
3. "Sparrow Hawk"
4. Opposition

## 2. Countering The Turning Performance Of A Better Subsonic Aircraft

Forcing The Opposition To Enter A Low Speed S Shaped Movement

When the two planes approach each other from two sides, they always use decreased speed, the crisscross passing tactic and each does their best to fall behind its opposition. In this type of situation, the "Sparrow Hawk" can use a small nozzle deflection of  $20^{\circ}$  to force the opposition to enter an S shaped movement. At this time, conventional aircraft must reduce the throttle and open the reduced speed plate. If they very quickly approach the state of losing speed they can almost have no movement capacity even to the point of not being able to operate. However, the "Sparrow Hawk" can draw support from the reaction control system to maintain good operation capacity and use the rotating nozzle to quickly reduce speed. Because of this, the opposition finds it very difficult not to fly in front of the "Sparrow Hawk" and enter the field of attack.

Making A Right Angle Turn. When the "Sparrow Hawk" is being pursued, it can draw support from the nozzle with a large deflection of  $60^{\circ}$  to  $70^{\circ}$  to complete a right angle turn and then suddenly by means of a very small turn radius changes course. Afterwards, it rolls, lifts its nose and turns to just behind the opposition.

### 3. Countering A Small Formation of Planes

When two opposing small formations are combating, the "Sparrow Hawk" first disperses itself forcing the opposition to dissolve its regular formation. The United States Marines flight personnel consider that the simultaneous tracking of two "Sparrow Hawks" is almost impossible. Only by using suitable thrust directional change can two "Sparrow Hawks" effectively disrupt the opposition's small formation.

#### The Principle Analysis And Utilization Limitations Of "Thrust Directional Change In Forward Flight"

Tests show that the hanging absolute altitude of the "Sparrow Hawk" aircraft is 2,195 meters. At an even greater altitude, no matter what the weight, this aircraft cannot hang. If there is already a certain speed used for thrust directional change, circumstances are different. It can be seen from chart 6 that when the nose deflection is at a smaller angle, the thrust lift weight is greater and forward flight thrust loss is very small. The sine of the thrust lift and deflection angle make a proportion that grows larger and the cosine of forward flight thrust and deflection angle make a proportion that decreases. When the nozzle deflection angle is  $15^\circ$ , the thrust lift will be slightly larger than  $1/4$  of the total thrust (or with the result of  $0.25g$ ) and the forward flight

thrust loss will only be 3.5% which can be overlooked. At this time, the wing lift not only does not decrease but on the contrary has increased this thrust lift weight with the result that the aircraft's mobility is raised enormously. If the nozzle deflection angle in forward flight is very large, forward flight thrust will then greatly decrease causing aircraft speed to slow down to the extent of slowing to near a "hanging" state. For example, when at an air speed of 600 nautical miles/hour (1,130 kilometers/hour), nozzle deflection will be  $98^\circ$  and then it will be able to reduce speed to 360 nautical miles/hour (686 kilometers/hour) in the 10th second and will be able to reduce speed to 200 nautical miles/hour (370 kilometers/hour) in the 28th second. Because it relies on the directional change of the thrust vector to reduce speed, as soon as the nozzle returns to a level position, 90% of the thrust can be used for acceleration. For example, after 15 seconds the air speed can be increased from 200 nautical miles/hour to 300 nautical miles/hour (556 kilometers/hour, after 26 seconds it can be increased to 400 nautical miles/hour (740 kilometers/hour) and after 45 seconds it can be increased to 500 nautical miles/hour (927 kilometers/hour).

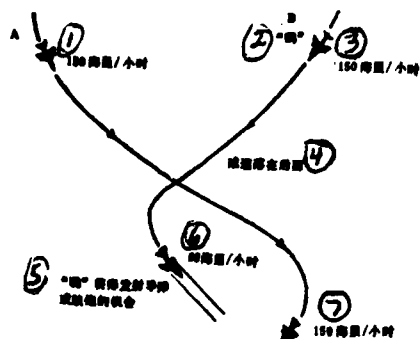


图5 低速蛇形机动

Chart 5 Low Speed S Shaped Movement

1. 150 nautical miles/hour
2. "Sparrow Hawk"
3. 150 nautical miles/hour
4. Reduced speed falling on rear side
5. "Sparrow Hawk" obtained opportunity to fire missiles or artillery
6. 90 nautical miles/hour
7. 150 nautical miles/hour

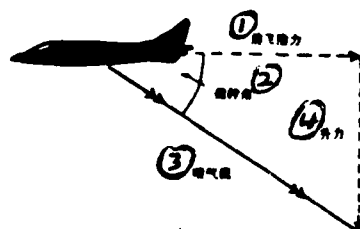


图6 "前飞中推力转向"的动力分析

Chart 6 Dynamic Analysis Of "Thrust Directional Change In Forward Flight"

1. Forward flight thrust
2. Deflection angle
3. Jet stream
4. Lift

In the beginning, when designing the "Sparrow Hawk", they did not yet consider the problem of thrust directional change in forward flight. Thus, it was discovered in test flights that this aircraft has the following limitations in technical utilization:

When flight speed is greater than 250 nautical miles/hour, if there is deflection of the nozzle, thrust does not exceed 80% of the entire thrust.

When flight speed is 300 to 400 nautical miles/hour, the nozzle deflection angle is not greater than 45°.

When flight speed is greater than 400 nautical miles/hour, the nozzle cannot turn in forward flight.

To decrease these limitations, it is necessary to make some improvements in the structure of the aircraft and engine such as strengthening the nozzle's movable neck, gearing and bearing ring.

Later period "Sparrow Hawk" aircraft improved and used the "Flying Horse" 103 engine. Thrust increased 1,360 kilograms and the surge surplus degree was also enlarged. Responding to the demands of the United States Marines, they improved the nozzle gearing and installed a larger powered motor to drive the nozzle. After

improvements, the utilization limitations of thrust directional change in forward flight were greatly decreased. For example:

At an altitude over 4,580 meters, the utilization of thrust directional change was totally without limitations.

At an altitude of 3,050 to 4,580 meters and an air speed smaller than 450 nautical miles/hour, there were no utilization limitations.

At an altitude lower than 3,050 meters and an air speed less than 300 nautical miles/hour, there were no utilization limitations.

When the speed exceeded the above mentioned formulations, the largest deflection angle of the nozzle was limited to 45°. Otherwise, it was necessary to make greater improvements and install greater powered gearing.

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